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Agricultural Research

Forecast: Drought-Resistant Crops

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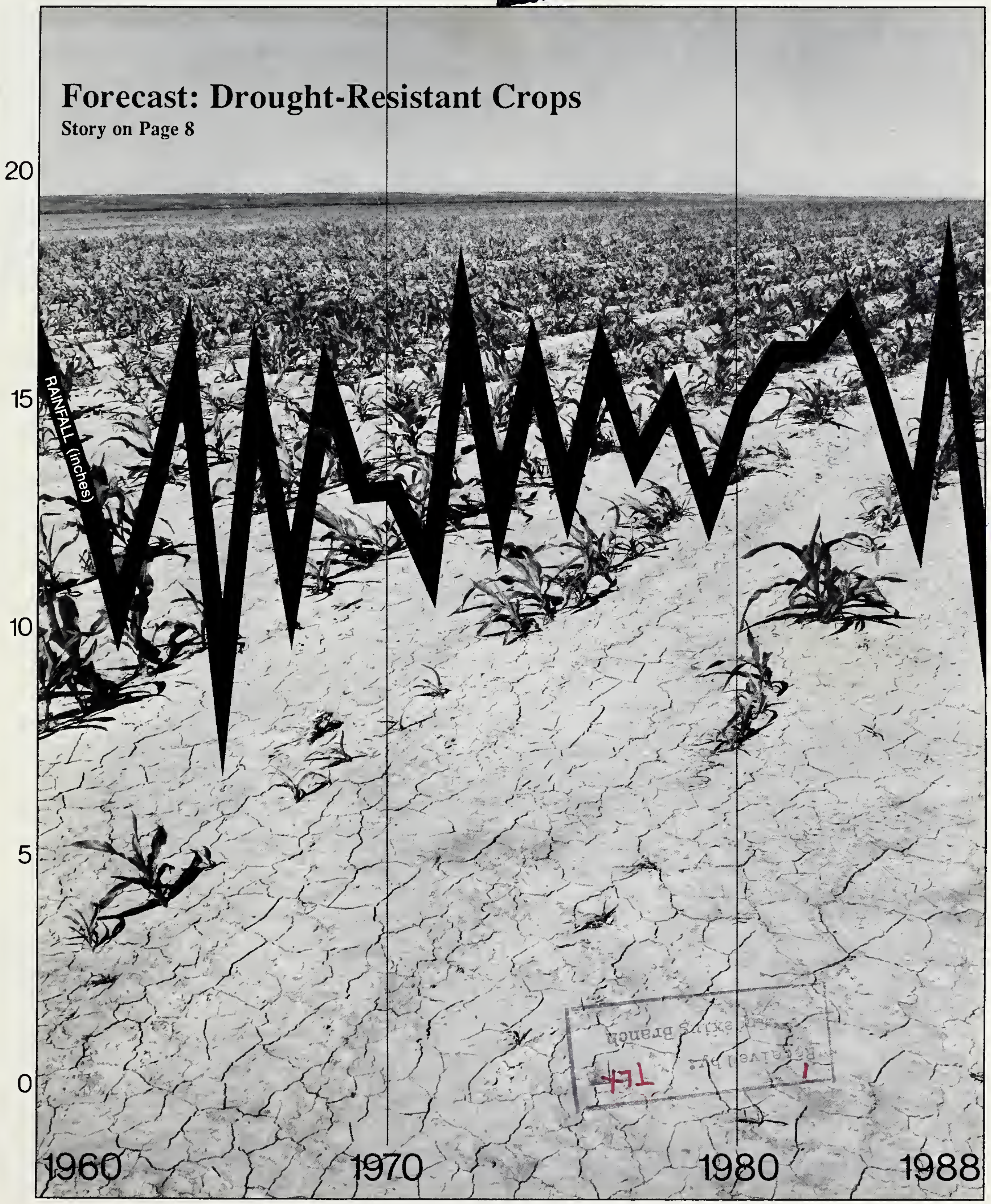


Conservation Offers Best Odds in a Drought

Other than rain, the answer to the drought of 1988 is the same as that for the energy crisis of the 1970's: conservation.

The energy crisis caught many Great Plains farmers by surprise. They had decided to ignore the area's erratic rainfall, averaging 19 inches a year, and rely on irrigation fulltime. Then the price of a barrel of oil skyrocketed, so the farmers couldn't afford to run their irrigation pumps.

U.S. Department of Agriculture researchers were ready to help farmers switch back to dryland farming because they'd been studying water conservation for 40 years. Those same techniques for making water go farther are especially useful in drought years.

For examples of water conservation technology, the USDA Agricultural Research Service's Conservation and Production Research Laboratory in Bushland, Texas, is a good place to start. The lab celebrates its 50th anniversary this year. During those years, scientists there have developed many innovative ideas such as the system of limited irrigation on dryland.

LID, as it's called, combines adjusted seeding rate with partial irrigation and a series of small earthen dikes across the width of some furrows. Seeds are planted farther apart at the ends of rows to reduce plant density and water use there. The dikes hold rainwater in small ponds, giving it time to soak in rather than run off the ends of rows.

LID relies on rain to furnish water to the ends of the furrows. The upper parts of the furrows are watered by keeping irrigation valves open for only a limited amount of time. This eliminates running irrigation water for several hours longer just to wet the ends, with great waste of water.

Furrow dikes such as those used with LID were developed in the early 1940's by a Colorado farmer. The technique was forgotten until ARS picked it up and refined it about 10 years ago, and it is being used by farmers now. Dikes can be used both in irrigation furrows and in the furrows between raised beds used with ridge tillage.

Bushland scientists also had an early role in another form of conservation tillage, probably the most widely used cultural technique the agency has developed. The technique is popularly known as no-till because it consists of disturbing as little soil as possible. One year's crops are planted directly through the residue of the previous crop. The residue slows down the evaporation rate of soil water and protects soil from eroding, just as mulches do for home gardens.

In fact, shortly after the Bushland lab was formed in 1938 in the wake of the Dust Bowl, scientists there turned to stubble mulching, an early form of conservation tillage, to reduce wind erosion. USDA's Soil Conservation Service operated the lab until the research was turned over to the newly created ARS in 1953.

Furrow dams trap rain or snow allowing moisture to seep into soil. (88BW1385)

Ironically, it was the energy crisis that gave a real boost to conservation tillage. Fewer trips with a tractor across a field mean fewer gallons of fuel used. Although conservation tillage is being used more and more each year, the pace of adoption slowed after the precipitous rise in fuel prices faded into memory.

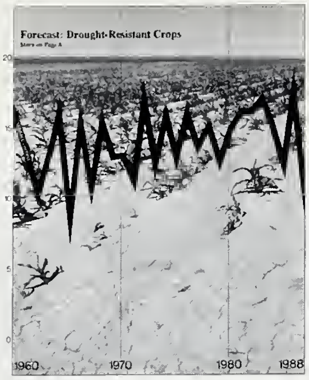
Now a new crisis has brought water conservation to the forefront, and conservation tillage has probably received another boost.

Agency scientists are prepared for calamities such as droughts because they take the long view. They study water conservation whether there is a drought or not. The results of their work, communicated to farmers and ranchers over the years, offer a way of bettering the odds of surviving a drought.

But a serious enough drought—and this one is the worst spring drought in many areas in this century—can defeat the best laid plans be they conservation tillage, drought-resistant crops, or furrow dams.

Working hand in hand with the Soil Conservation Service and other USDA agencies, ARS continues to refine and develop new techniques. Some are high tech and some are not; all have their roots in the soil and common sense.

James F. Parr
ARS National Program Leader
Dryland Agriculture and Soil Fertility



Agricultural Research

Farmers need to be prepared to face drought in any year, given the unpredictability of rainfall. Agricultural scientists are helping meet this challenge by breeding drought-resistant crops, by redesigning tillage methods to conserve soil moisture, and by improving irrigation systems that supplement rainfall, as well as making permanent irrigation systems more efficient.

Cover graph shows rainfall in the state of Kansas for January-June 1960 through 1988. Data courtesy of Eldon J. Thiessen, Kansas Agricultural Statistics. Photo of drought-stricken grain sorghum in Kansas copyrighted by Grant Heilman Photography.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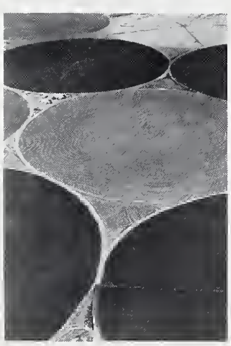
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DEPARTMENTS

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Dyer's Woad Wages Chemical War In West

A weed called dyer's woad, which uses its own toxic arsenal against neighboring plants, is infesting parts of the West.

When seed pods fall to the ground and rot, they exude a toxin that kills the roots of nearby grasslike plants, including those that cattle graze, says range scientist James A. Young of USDA's Agricultural Research Service in Reno, Nevada.

If the chemical could be synthesized, he theorizes, it might be turned into an environmentally safe herbicide. But, that's all down the road.

"Our immediate goal is to learn how and why dyer's woad thrives and to figure out how to keep it from spreading," Young says.

Dyer's woad *(Isatis tinctoria),* which was used in Europe for thousands of years to make blue dye, may have come into this country in the 1920's. Seeds may have been included in alfalfa seed imported from Ireland.

Over the years, the 3-foot-tall weed has taken hold in California, Oregon, Utah, and Wyoming. "It didn't become a problem in California until well after World War II."

Dyer's woad is hard to eradicate because it has more than one strategy to ensure its survival. Not only does the weed inhibit germination of nearby weeds, it also crowds out what's left of its competition, forming big, leafy rosettes that smother surrounding plants, especially cheatgrass and other weedy grasses that provide food for livestock and wildlife.

Young's curiosity was piqued when he noticed the weed had spread into northern California fields already infested with other weeds. In laboratory and field studies, he discovered how the toxin in rotting seed pods clears the way for the weed.

The process is called allelopathy—one plant species secretes a chemical

Dyer's woad in bloom. (88BW1382

that inhibits the growth of other species. The only way neighboring plants can be saved from dyer's woad, Young says, is by spring rains that soak into the ground and flush away the toxic chemical.

In northern California, the weed infests hay fields and thus lowers the quality of forage used to feed cows. North of Salt Lake City, entire hillsides are virtually covered with dyer's woad. These hills turn from bright yellow in the spring, when the plant sets seed, to deep indigo or black around June 15, when the plant dies off. "At that time, areas infested with the weed look as if they'd been charred by fire," says Young.

Woad has a venerable legacy. It may have originated in central Asia., then, following the westward migration of civilization, spread to Europe. After itinerant dyemakers abandoned an area, local farmers noticed that their fields would "woad" for years after the dyers had gone.—By **Howard Sherman,** ARS.

James A. Young is in USDA-ARS Landscape Ecology of Rangelands Research, Reno, NV 89512 (702) 784-6057. ♦

Farmers Sell Strawberries All Summer

Now the sweet tang of spring berries can bring profits to Northeast and Midwest producers throughout the summer. Thanks to Tribute and Tristar, strawberry varieties with reset biological clocks, the season for luscious strawberries promises to extend the profits of berry farmers by 4 months.

A few years ago, Agricultural Research Service scientists bred the two everbearing varieties, which can trace their origin to the lab of geneticist Gene J. Galletta.

"We've had to wait to see that Tribute and Tristar lived up to expectations," says Galletta, "but it's starting to happen. Growers are finally saying they are harvesting an abundance of summer strawberries that will continue well into October."

If growers irrigate to offset the heat, he says, this could become the longest of all strawberry seasons in states reaching from Massachusetts to Maryland and Minnesota.

Galletta, based in Beltsville, Maryland, said the two varieties were released to nurseries in 1981. But after release, growers needed time to learn how to adjust their irrigation practices to nurture root systems that are smaller than those of the spring-bearing varieties.

But the two varieties have finally been coaxed into taking hold, and now growers have a new chance to increase income. "While most farm crops return less than $1,000 per acre for the farmer, it is now possible to gross $25,000-$30,000 an acre or more by selling the berries at higher, out-of-season prices," Galletta says.

The late-bearing fruit are valued by homeowners as well as commercial growers. Galletta says that they are the best-tasting everbearers yet, every bit as juicy as standard varieties. Their keeping quality makes them ideal for either fresh market, or processed fruit products such as jams and jellies.

Tristar and Tribute are the products of a 20-year breeding effort to transfer a light-insensitive gene from a Rocky Mountain strawberry species into the new varieties. As a result, Tribute and Tristar are neutral to length of day.

"This makes them different from earlier plants whose biological clocks only initiate flowers in the fall, which

keeps them from fruiting until the following spring." Additional selling points include high yield, winter hardiness, disease resistance, and the fact that they produce a harvest the same year they are planted.—By **Karen Mehall,** formerly ARS.

Gene J. Galletta is at the USDA-ARS Fruit Laboratory, Bldg. 004, BARC-West, Beltsville, MD 20705 (301) 344-4652. ♦

Computerized Apple Records Bumps

Apple abusers, be forewarned. A computerized "apple" may tattle on hard knocks that can damage fruit.

Just 3-1/2 inches in diameter, the battery-powered gizmo is an ingenious assembly of electronic parts cast in a sphere of beeswax. "It's small enough to be packed in containers with real apples," says Galen K. Brown, a U.S. Department of Agriculture engineer.

"The artificial apple automatically records the bumps that real apples receive as they're moved from orchards to retail stores," says Brown, who is with USDA's Agricultural Research Service in East Lansing, Michigan.

Apple losses after harvest—caused by damage from handling, shipping, and storing—total millions of dollars annually. Because fresh apples command higher prices than processed apples, growers prefer to minimize damage rather than sell their fruit for applesauce.

Brown adds that the invention could be scaled up or down and reshaped to study damage to citrus, melons, peaches, tomatoes, potatoes, and cucumbers.

Inside the apple is an accelerometer to measure the force and duration of bumps. A clock records the precise time when each bump occurs.

These data are memorized and later fed into a personal computer that is set to notice only those bumps hard enough to cause damage. Later, researchers can compare the history of impacts revealed in the printout with actual bruises on the fruit.

Packed alongside fruit, this electronic imposter helps evaluate handling procedures from packinghouse to market. (88BW874-19)

The computerized apple is the product of cooperative research between a team of ARS and Michigan State University engineers.

Since last fall, the apple has been tested in several packing lines. It consistently helped researchers pinpoint locations in the handling system where damage occurs and recommend improvements in equipment and handling procedures to reduce apple damage.

Last November, the apple was packed in containers with real apples and field-tested in trucks on trips of 30 to 360 miles.

On truck runs, the least damaged apples were held in a cell pack, a plastic foam pack encasing each apple in an individual cell. "Regardless of mileage, a short section of rough highway can take its toll on even carefully packed apples," Brown says.

By adding other sensors to the apple, temperature and humidity data could also be recorded to help evaluate conditions during storage and transport.—By **Linda Cooke,** ARS.

Galen K. Brown is in USDA-ARS Fruit and Vegetable Harvesting Research, Michigan State University, East Lansing, MI 48824 (517) 353-5185. ♦

Early Sex May Doom Pear Psylla

A biological approach once considered a failure is being resurrected by Agricultural Research Service scientists to deal with pear psylla—tiny bugs that reduce the vigor of pear trees and cause ugly black scars on pears grown in the Pacific Northwest.

Psylla are brown and orange jumping plant lice about an eighth of an inch long. Like aphids, psylla damage trees by sucking their juices and excreting a kind of "honeydew," which drips onto the pears. Mold and bacteria that grow in this honeydew invade and damage pear skins, greatly reducing their value.

"Psylla are difficult to control with conventional insecticides because they rapidly develop resistance to them," says ARS entomologist James L. Krysan in Yakima, Washington.

Twenty years ago, ARS entomologists showed that juvenoids—compounds that mimic an insect's juvenile hormones—could, among other things, interrupt a dormancy-causing process called diapause in insects, says Krysan. But all attempts to use the compounds to control specific insects by prematurely ending dormancy failed.

"So the concept was relegated to the scrap pile of ideas that didn't work," he says. "Recently, though, we recognized that psylla was unusual—the diapause seems weak, and survival of psylla females might depend on when she mates."

"Our research suggests that juvenoids may kill psylla by affecting when they mate," he says. Pear psylla reproduce several times a year, but they spend the winter in a unique winter form.

Beginning in autumn, they become reproductively dormant until the following spring. That way, egg laying and hatch are synchronized with the springtime appearance of leaves on pear trees.

"A key target in controlling psylla is the overwintering generation," he

(Continued from page 5)
says. "If orchardists drive psylla populations to low levels at this stage, they can more easily manage the insects throughout the summer."

To find new control tactics, the scientists focused on the overwintering generation of psylla. They found that the females were sexually immature in autumn. "Much to our surprise," says Krysan, "we also discovered that males were sexually mature and sexually active at that time of the year."

In autumn, however, very few females were found to be mated. Field studies can be interpreted to mean that those females that were mated in autumn tended not to survive the winter. So, it appeared that psylla might be vulnerable.

In lab tests and in the field, Krysan and coworkers applied very low doses of juvenoids to normally dormant psylla. Juvenoids sped up development of the ovaries and caused males to mate with females. They also found that eggs laid by psylla treated with juvenoid do not survive the winter.

It takes only a drop of juvenoid the size of a speck of dust to make a male psylla sexually active or cause a female's ovaries to develop.

"For good control, all pear growers in a psylla-endangered area would have to spray their trees in autumn," says Krysan. "But with so few alternatives available for controlling the winter form of psylla, simultaneous spraying may be seen as acceptable."—By **Howard Sherman**, ARS.

James L. Krysan is at the USDA-ARS Yakima Agricultural Research Laboratory, 3706 West Nob Hill Boulevard, Yakima, WA 98902 (509) 575-5945. ♦

Fungus Sides With Bug Against Weed

A unique seed-eating insect and a bunch of hitchhiking fungi are teaming up to provide farmers with dual biological control for velvetleaf, a serious weed throughout the north-central and southern United States.

Robert J. Kremer, a microbiologist with the Agricultural Research Service in Columbia, Missouri, says the insect feeds on immature velvetleaf seeds found among row crops. And the fungi, which ride on the insect's stomach, back, and legs, mop up the remains.

"What happens is kind of like when a nurse tries to find a vein when taking blood," he says. "The bug probes the outside of the seed to find a good place for a direct puncture, then the fungi use that opening to get into the seed."

The insect, *Niesthrea louisianica*, uses sharp, sucking mouthparts to penetrate the soft coating of the seed and drain its contents. The fungi are then able to infect the weakened seed, leaving it discolored and shriveled.

Only about 5 percent of the seeds attacked by the duo are able to survive and germinate, Kremer says, "which indicates that this economically important weed can be dramatically decreased by using these two biological control agents."

Farmers may someday be able to introduce the insect to fields where velvetleaf is a problem, eliminating at least one application of herbicide in the process.

In tests on plots in Mississippi and Missouri, Kremer and entomologist Neal Spencer put *N. louisianica* in large screen cages over flowering velvetleaf plants. The number of insects per cage ranged from none to 50, depending on location.

Over a period of 2 years, the insects fed intensively on the developing seeds and produced several generations that lived on the plants. In Missouri, the insects successfully survived the winter, although they emerged later than those in Mississippi. More than 90 percent of the insects that ate velvetleaf seeds were found to carry fungi, mostly from the genera *Fusarium* and *Alternaria*.

The insect will not attack crops, Kremer notes. It eats only the seeds of velvetleaf and, to a lesser extent, prickly sida and spurred anoda, two southern weeds that have recently emerged in the Midwest.

Velvetleaf afflicts such row crops as soybeans, corn, and cotton. A single plant can set up to 8,000 seeds. Many of them are dormant; they can germinate after lying in the soil up to 50 years or more.—By **Matt Bosisio**, ARS.

Robert J. Kremer is with the USDA-ARS Crop Production Research Laboratory, Waters Hall, Room 216, University of Missouri, Columbia, MO 65211 (314) 875-5357. ♦

Feel Cold? Iron Out the Goose Bumps

If your body can't stand up to the cold, you may not have enough of the right stuff—iron—even if you're not anemic.

According to Henry C. Lukaski, a physiologist with the Agricultural Research Service in Grand Forks, North Dakota, a recent study of women indicates that the ability to regulate or maintain body temperature in the cold may depend on the amount of iron consumed daily.

"Changes in metabolism occur before you see anemia, or iron deficiency," says Lukaski, who measured the women's body heat after they donned swimsuits and sat in a chilly room until they began to shiver.

The metabolic changes are related to stored iron, measured by blood levels of the iron-storage protein ferritin, rather than to blood hemoglobin concentration, the traditional measure of iron status, says Lukaski.

For 80 days, six healthy young women gave blood for biochemical measurement and consumed one-third of the Recommended Dietary Allowance of iron for women in child-bearing years (6 milligrams daily, instead of 18). They then ate an iron-adequate diet for 114 days with an iron supplement for the last 26 days.

After each intake period, the women sat in an environmental chamber with a constant temperature of 64°F and a gentle breeze. On average, they lost 29 percent more

body heat after the low-iron period than after the supplemented period. And they felt generally colder during the low-iron period.

"Because more than half of American women in the 11- to 50-year-age group consume less than the recommended iron intake," he says, "impaired thermoregulation in moderately cool and cold temperatures may be quite prevalent."

This can be corrected by eating more iron-rich foods such as lean red meat, fish, poultry, beets, beans, and leafy green vegetables and by drinking orange juice with meals. Vitamin C in the orange juice increases iron absorption.

The women's average hemoglobin concentration was within the normal range, although at the low end, after the low-iron period and increased only slightly after the supplemental period. However, during the chilling test, their internal (core) and skin temperatures both dropped after the low-iron period, even though their hormonal "thermostat" was turned up, he notes.

The "thermostat" is norepinephrine, a hormone that is responsible for increasing metabolism and heat production. Despite higher blood levels of norepinephrine, the women produced 9 percent less heat when their iron stores were depleted.

And they lost more of the heat they did generate, Lukaski says. "The furnace was going, but the windows were wide open."—By **Judy McBride,** ARS

Henry C. Lukaski is at the USDA-ARS Human Nutrition Research Center, P.O. Box 7166 University Station, Grand Forks, ND 58202 (701) 795-8429. ♦

New Matmaker Hastens Hay Making

A new machine could save farmers time and increase the value of their hay by letting them mow it in the morning and dry and bale it in the afternoon instead of days later, reports a scientist at the Agricultural Research Service.

BRUCE FRITZ

Richard G. Koegel displays a section of matted alfalfa that was mowed, shredded, and pressed into a continuous mat by his prototype harvester in background. (88BW0953-21)

A working prototype called the forage mat machine mows and immediately shreds alfalfa, says agricultural engineer Richard G. Koegel of ARS' U.S. Dairy Forage Research Center in Madison, Wisconsin.

"The machine then presses the shredded leaves and stems into a continuous, quarter-inch-thick mat and lays it on the stubble to sun-dry in 6 hours or less," he says. "The hay can be baled the same day if it sun-dries to the 20 percent moisture content required for baling."

That means less chance of rain damage to the crop. Also, hay processed by the new machine and fed to sheep was about 15 percent higher in fiber digestibility than hay cut and dried conventionally.

Using conventional equipment, called a mower-conditioner, a farmer normally waits 2 to 4 days for alfalfa to sun-dry to 20 percent moisture. A mower-conditioner crimps the stems, opening cracks that help them dry, but the leaves tend to dry faster—and may shatter from the stems and be lost during baling.

In contrast, the forage mat machine by shredding the plant exposes a lot of moisture, and this juice acts as adhesive to bind a homogeneous mix of leaves and stems into a mat that dries quickly and uniformly.

"Gently placing the mats on the stubble without broken spots is the most challenging aspect of our work. And keeping a thickness of no more than one-quarter inch is critical to keeping drying time down," Koegel says.

After sun-drying, the hay is ready for harvesting by conventional methods, if desired. Round baling seems the easiest choice. For square baling, he thinks a baler that could fold the material like an accordion would be best. For silage, some way to pick up the hay and break up the mat structure before the hay is blown into the silo is needed.

An equipment manufacturer has started commercially developing the new machine. Koegel says they plan to refine the process so it will work with grasses as well as alfalfa.—By **Linda Cooke,** ARS.

Richard G. Koegel is at the U.S. Dairy Forage Research Center, 1925 Linden Drive West, University of Wisconsin, Madison, WI 53706 (608) 263-5636. ♦

Cultivating an Indifference to Drought

In many parts of the country, from South Carolina to the northern plains, it doesn't take much to bring on a regional drought—just 2 weeks without rain will do it. Areas such as southern Texas are even more drought prone. But a drought like this year's, in which large portions of the United States experience prolonged shortage of rainfall coupled with high temperature, isn't a frequent event.

Whether a localized, regional, or nationwide phenomenon, drought carries with it economic hardships that cannot be discounted. Because little can be done to alter atmospheric conditions, scientists have turned their attention toward mitigating the effects of drought.

Agricultural Research Service researchers are developing crop varieties that can grow and yield at commercial levels, whether or not drought is a factor.

One such crop is a drought-resistant forage grass, developed by ARS scientists at Woodward, Oklahoma. Besides helping control erosion, the variety—WW-Spar bluestem—already boosts forage production on more than 1 million acres in the southern plains.

Chester L. Dewald, an agronomist at the Southern Plains Research Center in Woodward, led in the development of the variety, which was released cooperatively with the Oklahoma Agricultural Experiment Station in 1982.

WW-Spar comes up faster, stays green longer, and produces quality forage even under drought conditions better than other Old World bluestems. With proper management, WW-Spar is three to four times more productive than native grasses in the southern plains.

"Cattle cannot overgraze it. After drought or in small pastures where the grass looks completely gone, WW-Spar comes back just as hardy as ever after a normal rain," says Cletus Carter, a Beaver County, Oklahoma, cattle rancher and seed producer. "We figure we get 25 percent more grazing than with other varieties." He also owns High Plains Seeds, in Forgan, and in the last 2 years has planted 16,000 acres of WW-Spar.

Weldon Miller, owner of Ag-Renewal in Weatherford, Oklahoma, agrees, "WW-Spar has been a tremendous lifesaver for farmers in Texas and Oklahoma."

DAVID NANCE

In Oklahoma, seed from a forage grass, WW-Spar bluestem, is harvested by Woodward Flail-Vac Seed Strippers. (88BW1369-9)

WW-Spar bluestem is a valuable grass for beef production when used as an improved pasture, with proper fertilization, or as rangeland plantings. "Protein ranges about 12 to 13 percent in the hay stage. After the seed is harvested, the remaining forage contains 6 to 8 percent protein," says Carter.

To further boost the grass' potential, Oklahoma rancher Aaron Beisel, with Dewald's help, developed a new machine to harvest the chaffy seed. Beisel patented the machine—the Woodward Flail-Vac Seed Stripper. About 500 machines have been sold commercially, making it possible to speed supplies of WW-Spar and other grass seed to farmers. Other crops being bred to produce with less water are:

Hycrest, a forage grass developed by Kay H. Asay, along with his co-workers. Asay is a geneticist with the Agricultural Research Service's Forage and Range Research Laboratory in Logan, Utah. Hycrest brings good grazing to ground that has received less than 8 inches of rain, acres that would normally be sprouting just a few wisps of grass.

"Cattle cannot overgraze it. After drought or in small pastures where the grass looks completely gone, WW-Spar comes back just as hardy as ever after a normal rain."

Cletus Carter, Oklahoma cattle rancher

"Hycrest doesn't seem to be bothered by the lack of rain," says Asay. "We've gotten as much as 90 percent establishment in areas that received only 6 to 8 inches of precipitation. In contrast, standard wheat grasses establish at only 50 percent under the same conditions."

Hycrest gets its ability to tolerate dry weather conditions from a faster growth

DAVID NANCE

Drought-resistant WW-Spar bluestem seed is inspected by Weldon Miller, licensee to manufacture the Woodward Flail-Vac Seed Stripper. (88BW1367-18A)

rate as a seedling and because it has a larger seed compared to crested wheatgrasses," Asay says. "As a cross between species, it also has substantial hybrid vigor."

Since Hycrest's release to seed companies and growers in 1984, there has been tremendous demand for the grass, and it is replacing other crested wheat grasses as the standard in some areas. In 1988, it is estimated that over 5 million pounds of seed will be sold.

Pearl millet, which is being developed to yield up to 25 percent more under severe drought conditions. Pearl millet is grown as forage in the United States and as a grain crop in many arid less-developed countries, explains Glenn W. Burton, an ARS geneticist at the Georgia Coastal Plain Experiment Station in Tifton, Georgia. Burton has traced the variety's drought tolerance to a single recessive gene, *tr*. The expression of the gene causes the plant to have leaves with a thick, shiny waxy "skin," or cuticle. Varieties that are less drought tolerant have a less waxy cuticle and the leaves have tiny surface hairs.

"It almost looks in the drought-tolerant variety as if the hairs (which are made of cuticular material) have melted down to fill in microscopic cracks and crevices on the leaves' surfaces," he says. "This limits moisture loss."

As genetic engineering techniques become more sophisticated, Burton expects it may be possible to introduce the *tr* gene into other grain crops, conferring drought tolerance to wheat, oats, corn, and others.

Peanut plants that send their roots deeper into soil in search of water are being sought, according to ARS plant physiologist Darold L. Ketring, of the Plant Science Research Laboratory in Stillwater, Oklahoma.

He is screening plant varieties from as far away as Africa and India in an effort to find those with more root density and length and ability to maintain plant hydration.

"The problem is not so much finding a plant that grows well on less water, it's producing a plant that can get to more water on its own," Ketring says. "When you consider that 65 percent of the peanuts grown in the United States are not irrigated, you can imagine how vulnerable to drought the crop is."

Inoculations with **the fungus VAM** (vesicular arbuscular mycorrhizae) may enable many crops to extend their root systems, according to microbiologist James R. Ellis, at the ARS Soil and Water Conservation Laboratory in Lincoln, Nebraska. The fungi's filaments lengthen the plant's root hairs and have a smaller diameter than the root hairs. This allows the root access to small pores in the soil where water is stored, according to Ellis. A typical root hair is 30-40 micrometers, whereas the fungus filaments or hyphae can be as small as 10.

In moisture-deficient situations, VAM-inoculated wheat yielded 10-20 percent more than the same wheat grown without the fungus.

Another microorganism, **rhizobia**, can also enhance drought tolerance. These bacteria are associated with soybeans and other legumes that allow plants to take nitrogen from the air instead of from fertilizers. Soybeans grown in the Southeast are usually treated with rhizobia before planting to increase yields.

Patrick G. Hunt, research leader at the Coastal Plains Soil and Water Conservation Research Center in Florence, South Carolina, has found that under drought conditions, soybean yields varied with the strain of rhizobia used in the inoculation.

Rhizobia have been, up till now, investigated mostly for their ability to accumulate nitrogen. But Hunt believes as irrigation water becomes more expensive, commercial producers of rhizobia may consider drought tolerance to be an important characteristic as well.

Working with **blueberries**, plant geneticists Arlen D. Draper and W. Alan Erb took a different research tack. Instead of working to enhance a particular mechanism within the plant, they checked many specimens to identify those whose genetic makeup allows them to grow with the least water.

The researchers found at least one cross that produced as many berries by weight whether it was irrigated three times a week or only once.

"With a cross like that, you could extend the range of blueberry country, " Erb says.

Citrus crops are also being screened, in a search for those varieties that can better tolerate drought, according to Joseph C. Vu and George Yelenosky of the ARS Horticultural Research Laboratory in Orlando, Florida.

Citrus farming has been moving steadily southward in Florida, following recent cold winters. Trees that require less irrigation would be more profitable for growers.

Vu has already noted enough natural variation to expect that improvements can be made in orange trees' water demand.—By **Linda Cooke** and **Kim Kaplan, ARS.** ♦

DROUGHT — A Farmers Diary

Our fictional farmer, caught up in anxiety caused by drought, can identify with the cumulative stress that his crops experience.

June 3 Today I finished planting the last of the field corn. Even though we could use some rain, the soil feels okay. If it rains tomorrow...

If it rains tomorrow, corn will sprout faster. That's because, when the soil is dry, most of a seed's nutritional reserves are used for root growth. In moist soil, the growing shoot receives a larger share of the available nutrition and shoots up faster.

At time of planting, if enough residual moisture is locked in the pores of the soil's root zone, the biological processes triggering seed germination and shoot emergence should be unimpeded.

June 18 Temp in the mid-80's and no rain. The corn's an inch high now and a little later than usual. If it rains tomorrow...

If it rains tomorrow, the seedlings still stand an excellent chance of recovering vitality, if they don't suffer other, concurrent stresses. Young corn plants are resilient.

While water is vital throughout a corn plant's development, it's critical at the seedling stage. A drought-stricken seedling will increase its root growth at the expense of the plant's top in a quest for more water. Slow growth now will reduce productivity later in the plant's life.

July 15 A thundershower yesterday dropped half an inch of rain. It won't help. Heat's bad. Corn leaves are tightly rolled in the daytime. If it rains tomorrow...

If it rains tomorrow, much damage has already been done. The harvest will be smaller; the quality may also be reduced; changes may have occurred in metabolic pathways that affect flavors.

For plants that have already been subjected to water stress, heat stress is doubly devastating. If the meristematic layer, a band of cells in the plant's shoot apexes, is burned, growth will stop. To prevent such burning and to conserve moisture, a plant may roll its leaves to reduce surface area exposed to the sun.

Heat can also raise the temperature of the soil, causing roots in that zone to die back. Once that happens, a light rain, one which doesn't reach down deeply, won't help the plant. And corn's pollen is highly temperature-sensitive. If extreme temperature or water stress occurs during the critical few days the plant is pollinating, yield will be zero.

August 5 Corn leaves are turning brown on the ends. I doubt if there'll be any harvest at all. Even hay is getting scarce and prices are going up. It's the worst drought I can remember. But if it rains tomorrow...

If it rains tomorrow, it seems unlikely that drought-stricken corn plants will fully recover. Water will restore the process of photosynthesis, providing that leaf cells are not injured. But after 2 devastating months of water deprivation, the limits of the growing season are approaching.

Water stress can result in irreversible damage to the plant systems. A leaf or vascular stalk deprived of water will desiccate and die. Fewer leaves means less photosynthesis; the plant is less able to produce its own food; as it dries, it also starves. Fighting for survival in this way, a corn plant will sacrifice fruition—it lacks the nutrient reserves needed to produce hormones triggering reproduction.

Still, today's scientifically bred corn varieties are tougher than their ancestors. Given thorough watering, field corn will struggle to resume its life processes.
—by **Regina Wiggen,** ARS

Technical information was contributed by John J. Burke, a plant physiologist in USDA-ARS Plant Stress and Water Conservation Research, Route 3, Box 215, Lubbock, TX 79401 (806) 746-5353.

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When It Never Rains Enough

While much of the nation suffered drought this spring and summer, some farmers were able to keep their crops alive by irrigation. Nearly 60 million acres—an area about the size of Oregon—are watered each year, although the acreage does vary from year to year depending on the amount of supplemental irrigation required in areas that depend largely on rainfall.

Thanks to irrigation, areas that early settlers once described as vast deserts now flourish. So crucial is irrigation water that to expect crop growth without it in the arid and semiarid West is similar to expecting houseplants to thrive with no water.

The prospects of expanding the acreage in the United States are not good, however. Dale A. Bucks, national program leader for water management with the Agricultural Research Service in Beltsville, Maryland, says, "There are no major untapped waterways left that could be developed economically for irrigation. Underground sources or aquifers can be depleted or lowered so far that energy to pump water to the surface becomes prohibitively expensive. Thus, the goal of irrigators must be to conserve as much water as possible."

"There are no major untapped waterways left that could be developed economically for irrigation."

Dale A. Bucks, Agricultural Research Service, Beltsville, Maryland

Farmers who irrigate must make difficult decisions all season long—how much water to apply and when. They know they must apply slightly more water than crops will use, but any excess beyond that is waste and can cause pollution.

The extra water beyond crop needs is needed to flush salts such as sodium chloride, sodium sulfate, and calcium chloride below the crops' roots. Salt accumulation is a natural consequence of irrigation; as water evaporates from the soil surface, the salts previously dissolved in the water are left behind.

This excess water is lost each year, more than enough to cover 25 million acres to a depth of 1 foot. ARS researchers want to find low-cost ways to reduce this loss and reuse the water on other crops.

Over the past four decades, agricultural scientists and engineers have worked to develop and refine more efficient irrigation systems and practices, including canals and other open waterways, overhead sprinklers, small plastic hoses, and buried tubes and tiles.

DAVID FALCONER

At the Eastern Oregon Farming Company near Hermiston, Oregon, over one-hundred center-pivot sprinklers, operated by a central computer, irrigate wheat, alfalfa, potatoes, and melons. Each pivot irrigates about 128 acres. (88BW1312-24A)

That work continues at several locations as ARS scientists develop the technology needed to safeguard our water and land for future generations.

Sprinkler Systems

Computers have taken on increased importance in helping the farmer make decisions about when and where to apply irrigation water.

In Fort Collins, Colorado, ARS engineers developed a computer program that cuts energy costs by about 15 percent and can cut water use up to 30 percent by telling farmers when crops need water. The latest version of that program, called SCHED, is now available and being used by irrigators, consultants, and county agents.

"The main advantage of this latest irrigation-scheduling program is that it's easier to use, yet it accurately predicts crop water needs. Special weather information, such as solar radiation data, supplied by some local radio stations or newspapers, contains enough data for the software program. For slightly more accurate results, users can enter on-farm weather data they collect themselves," says Harold R. Duke, agricultural engineer at ARS' Irrigation and Drainage Research Unit in Fort Collins.

Scientists originally developed the system to schedule irrigation on a 2,200-acre farm that had 15 groundwater pumps delivering water through sprinklers.

Weather and soil moisture data is electronically transmitted to the system at the farm headquarters from fields up to 6 miles away. Using this information and crop requirement data, the computer then recommends which pumps could be turned off to keep power consumption down and crop yield up.

The scientists are now refining the computer program to control water movement on 12,000 irrigated acres near the Oregon and Washington border. Water is pumped nearly 500 feet vertically from the Columbia River and diverted through a maze of auxiliary pumps and pipes with the computer helping decide which is the cheapest route and combination of pumps to use.

DAVID FALCONER

DAVID FALCONER

Above: ARS agricultural engineers Dale Heerman (right) and Gerald Buchleiter (second from left) work closely with farm managers Marvin Clarkson (left) and Frank Lamb (third from left) of the Eastern Oregon Farming Company to refine a computer program (SCHED) to control the sprinklers on the company's 12,000 acres of irrigated farmland. (88BW1308-34A)

Right: ARS agricultural engineer Dale Heerman (left) and Luke Maynard of the Eastern Oregon Farming Company check the radio telemetry equipment that controls water for five center-pivot sprinkler systems. (88BW1309-14)

Top, right: At Kimberly, Idaho, low-pressure sprinklers used in conjunction with furrow depressions help hold soil in place and conserve water. (88BW1298-19)

Bottom, right: Agricultural engineer Dennis Kincaid inspects mini-reservoirs made by a modified tillage instrument to trap and hold water until it seeps into the soil. (88BW1283-35)

SCHED runs on an IBM-PC or compatible computer. Potential users can obtain a copy by sending a blank, formatted diskette to Harold Duke or Dale Heermann, USDA-ARS Irrigation and Drainage Research Unit, Colorado State University, Fort Collins, CO 80523.

A commercial software package that incorporates parts of SCHED is now available to sprinkler irrigators. The new package saved one irrigator, Ken Goeglein, near Yuma, Colorado, more than 50 trips to his fields 20 miles away in just 1 month.

DOUG WILSON

DOUG WILSON

"The irrigator said savings in his time, plus gas and wear and tear on his pickup, coupled with reduced electricity consumption for pumps, paid for his computer and the software in the first year," says Heermann.

Additional energy savings result when irrigators lower the water pressure in overhead sprinklers. Motors and engines consume more electricity or fuel if they have to power pumps that force water out at higher pressures. But lowered pressure and reduced utility bills come at a cost. Low pressure delivers the same amount of water in a narrower pattern that is concentrated near the sprinklers, more like a downpour. Water can run off fields and erode valuable topsoil. And of course sprinklers have to be closer together and moved more often. With high-pressure sprinklers, the spray pattern is more like a gentle shower over a wider area.

ARS scientists are working to reduce erosion caused by low- pressure sprinklers by using tillage practices that leave residue from the previous crop on the soil surface to hold soil in place as sprinklers move slowly overhead.

Another method for halting erosion under low-pressure sprinklers is being studied at Kimberly, Idaho. There a machine alters the soil surface to leave small depressions that trap and hold water until it seeps into the soil.

Drip or Trickle Systems

Cotton plants produce 10 to 15 percent more cotton on 15 to 20 percent less water if they are irrigated with a drip or trickle system rather than with a level basin system. The above-ground drip system achieved these advantages on a variable, coarse-textured soil by using smaller, more frequent irrigations.

ARS' Dale Bucks, who measured this yield increase while he was based at Phoenix, Arizona, thinks trickle irrigation may become more popular if water costs escalate.

Surface Systems

Surface irrigation, where water flows mainly by gravity from canals into furrows or floods the fields, is the oldest and often most wasteful method. Yet surface irrigation accounts for more than 6 of every 10 irrigated acres in the United States.

Advantages to surface irrigation are that gravity flow largely eliminates costly pumping and can be automated with pneumatic or electric valves to regulate the flow of water.

ARS scientists and engineers are developing state-of-the-art technology to make surface irrigation systems as efficient as center pivot or other sprinkler irrigation systems.

• Level basin irrigation—where water flows onto perfectly flat fields completely surrounded by small control dikes—is being used increasingly in arid and semi-arid regions to conserve water. Fields are typically graded with laser-guided earth movers that level them to within a one-quarter inch accuracy.

A recent study has demonstrated that water seldom ponds for long times on level basins even in high rainfall zones such as Columbia, Missouri, as long as the soil has an infiltration rate similar to that of a loam or coarser soil.

"If this holds true for other areas, then level basins could be used more widely than previously thought. These basins are easy to manage, resist soil erosion, and trap snow and rain for crop use.

If the basins were used on fine-textured soils that restrict water infiltration, or in areas with high rainfall, we could design escape gates to drain excess water from these fields," says agricultural engineer Allen R. Dedrick at ARS' U.S. Water Conservation Laboratory, Phoenix, Arizona.

• ARS engineers at Phoenix have developed a simple and accurate way to measure water depth so they know how much is flowing in open irrigation canals. If the depth is known, irrigators can easily calculate how many gallons or acre-inches of water are going to each field. Until now, such sensors have been too costly for most agricultural uses and too inaccurate—hindering efforts to efficiently manage irrigation water.

The new technique measures the water level using an inexpensive pressure-measuring device (a transducer) coupled with two air bubblers positioned in the canal. The bubblers and electronic equipment continually recalibrate the transducer. The result is an accuracy within a tenth of an inch—up to five times better than many currently available techniques. The system costs the same or less than presently available equipment, according to Dedrick, and allows accurate measurement of water-

flow from remote locations when used with flumes or other flow-measuring devices.

ARS engineers are also developing gate control mechanisms that provide constant waterflow in irrigation ditches despite flow fluctuations created when water levels change in supply canals. Without accurate flow regulation, some fields get too much water while others get too little.

One flow regulator, called a Dual-Acting, Controlled-Leak system, uses a novel float device that eliminates complicated electronic equipment and doesn't require electricity. As the water level changes in the canal, the float moves. This movement opens and closes the irrigation gate. Fully electronic controls now used are accurate to ±5 or 10 percent while the new mechanism is accurate to ±2 percent. It can be easily fitted to most existing irrigation canals and structures, says agricultural engineer Albert J. Clemmens, its developer in the Phoenix lab.

• At Kimberly, Idaho, researchers at the Soil and Water Management Research unit have recently added infrared telemetry, similar to remote controls on televisions, to turn on and off the waterflow to six 10-acre basins or fields.

"This is better than radio telemetry, which has been used in the past, because it doesn't require a license and isn't bothered by electrical interference," says ARS agricultural engineer Allan S. Humpherys.

Underground Drip Irrigation Yields Record Tomato Harvest

A below-ground watering system that conserves increasingly scarce irrigation water has contributed to what is very likely the world's record production for field-grown tomatoes.

Soil physicist Claude J. Phene of the Agricultural Research Service, Fresno, California, says that he used thin plastic pipes, buried near the root system of the plants, to irrigate and fertilize the plants, then harvested 100 tons of ripe tomatoes per acre last year.

Plastic tubing is used for drip irrigation line. (0781X885-17)

In California, where Phene's research plots are located, the average irrigated tomato field yields 26 tons per acre. To his knowledge, his harvest breaks the previous record for field-grown tomatoes, which was 75 tons per acre.

Phene, an international authority on farmland irrigation, credits the underground watering system, known as subsurface drip irrigation, for boosting yields and for other benefits that other, more widely used cropland irrigation systems, such as overhead sprinklers or furrow irrigation, can't provide.

Although underground irrigation has been in use for some years, Phene's system is more sophisticated than most, because it is computer-controlled and linked to a scale that indicates the crop's current need for water. Even less sophisticated subsurface drip systems offer important advantages that can save farmers water and can protect the quality of water supplies, he says.

Underground drip irrigation not only increases each acre's productivity, which he says he has shown in his experiments with tomato, cotton, and cantaloupe, but can also increase yield quality.

With other systems, tomatoes, cantaloupe, and other crops may sometimes be lying on damp ground, which can accelerate rot or produce stains that make the crop worthless. With subsurface irrigation, the surface is dry. It's hard for some growers to get used to looking at dry ground, but as long as the plant roots are being fed, a dry surface is best for many fruits and vegetables. Underground systems also contribute to a uniformly high-quality crop, he says. "If you apply water to the surface of the soil, the water doesn't infiltrate evenly because of natural irregularities in the soil surface. But with below-surface pipes, you get more uniform application and thus more uniform growth of the crop from one end of the field to the other."

Underground irrigation reduces loss of irrigation water to evaporation, eliminates runoff of excess irrigation water from the field, and reduces drainage into the underground water supply. Such drainage, because it carries salts from the soil and from fertilizers, can cause pollution problems.—By **Marcia Wood**, ARS. ♦

Moisture sensors downfield detect when the water has traveled a basin's length. The sensors trigger the infrared transmitter to send a signal that closes irrigation gates to that basin. Simultaneously, cables attached to these gates open irrigation gates on an adjacent basin.

• Researchers are also looking at surge irrigation to prevent excess water application in the upper portion of long furrows. Surge irrigation takes advantage of a natural phenomenon—most soils absorb water slower if allowed a short rest period between irrigations. With this system, water flows down furrows in short pulses or surges, each usually lasting 20 minutes to 1 hour, depending on soil type. Each successive surge flows over areas previously wetted without soaking in as far as with conventional furrow irrigation.

A Dual-Purpose Buried System

In the southern Mississippi Valley, soils are plagued first by too much water, then too little. ARS researchers, led by agricultural engineer Cade E. Carter in the Soil and Water Management Team, Baton Rouge, Louisiana, are looking at drainage tiles to carry away the excess and then serve as a conveyance for irrigation water when drought hits. So far, engineers have tried the system on a 17-acre sugarcane field with tiles 50 feet apart and 3 feet deep. Yields were up 20 percent compared to untiled fields.

ARS agricultural engineers James L. Fouss and James S. Rogers are refining a computer program called DRAINMOD that might be used to predict crop needs and automatically run the pumps that drain and supply water to the tiled fields.—By **Dennis Senft,** ARS.

Dale A. Bucks is at USDA-ARS National Program Staff Headquarters, Bldg. 005, BARC-West, Beltsville, MD 20705 (301) 344-4034. ♦

Genetic Road Signs Point to Higher Yields

An Agricultural Research Service scientist is tagging corn genes with easily followed road signs that could take the guesswork out of breeding economically important traits into new corn varieties.

Charles W. Stuber, a geneticist with ARS in Raleigh, North Carolina, says the road signs act as easily spotted markers for tracing genes that control a certain trait—and for determining whether those genes have passed from parent plants to offspring.

This research may eventually lead to cutting in half the time it takes to develop corn with traits such as better disease resistance, increased sturdiness, and faster growth.

"Being able to track when a gene, and therefore a trait, has passed from donor to recipient or from parent to offspring should reduce the time needed to create a new variety from an average of 10 years to 4 or 5," says Stuber.

Based on earlier extensive field and laboratory studies relating markers to traits, he has already had some success at marking the gene sequences on the corn chromosomes that directly affect yield. He says, "By selecting strictly on genetic type based on the presence or absence of certain markers, we have been able to manipulate yield significantly in either direction."

Stuber sees yield as a major challenge because control of this trait involves so many genes.

Traditionally, plant breeders have depended on the time-consuming process of crossing parent stock, growing and evaluating the offspring, and selecting top performers. Then they continue making crosses or self-pollinations for several generations to fix the trait so it will always appear in the new variety.

Sometimes errors can be made in selecting top performing plants. They may have done well just by chance—by being in a good spot in the field, for example, rather than having improved genes.

Using about 70 markers, which were developed by Stuber and other researchers, to tag different parts of the corn's chromosomes, Stuber doesn't have to depend on such trial and error.

"If you think of the chromosomes as a highway across the United States, these unique markers act as easy-to-see road signs we've erected to point out 70 big cities. We're looking for a particular intersection—gene group—somewhere in one big city," Stuber says. "As more markers are developed, we'll be able to post signs at smaller and smaller 'towns' on the chromosomes."

To see whether the genes and their attached markers are present, Stuber grinds up a small piece of a gene-marked corn plant and places a sample of this into a gel. An electrical charge pushes the marker-gene products through the gel at different speeds, forming dark bands that can be read like the bar codes used on consumer products.

"Once the controlling genes are identified and a marker attached, you will be able to weed out unsuccessful offspring—whether you are doing genetic engineering in the lab or breeding in the field—without having to grow the plants to maturity," he says.

Stuber is not sure exactly how specifically he will be able to map controlling genes for all of corn's traits. But he says, his work gives breeders more direction than they have now. "I hope to be able to tell them, if you want to improve such and such a characteristic, concentrate on this particular chromosome."—By **Kim Kaplan,** ARS.

Charles W. Stuber is in USDA-ARS Plant Science Research, 3627 Gardner Hall, North Carolina State University, Box 7614, Raleigh, NC 27695 (919) 737-2289. ♦

Gene Transport Vehicles Found in Yeasts

Possible new vehicles for moving genes from one microorganism to another have been discovered in four strains of yeasts by an Agricultural Research Service scientist. These genetic molecules—strings of DNA called linear plasmids—may become biotech workhorses along with genetic molecules in bacteria to expand the roles of yeasts well beyond the ancient arts of making bread, alcohol, and fermented foods.

Research on linear plasmids is being done at ARS' Northern Regional Research Center in Peoria, Illinois. Agricultural Research Service geneticist Paul L. Bolen, who discovered the plasmids, is working under a cooperative agreement with the Biotechnology Research and Development Corporation of Peoria.

Until Bolen's discoveries, linear plasmids had been found in only one other yeast. None of the four yeasts he found them in is among the few used commercially today, but that may change, he says.

For example, one yeast found on grapes contains linear plasmids that might someday be used in making citric acid for soft drinks or amylase enzymes for breaking down cornstarch for fermentation.

In the past, commercial interest in expanding the use of yeasts may have been held back by limited knowledge of their biochemistry, says Bolen. "Now that we're gaining an understanding of the uniqueness and diversity of metabolic processes among species, we're beginning to envision a way of creating marketable products inexpensively through fermentation, using genetically engineered yeasts."

Linear plasmids, he says, may even work better than the plasmids that genetic engineers now typically use to shuttle genes between microorganisms.

"Those plasmids are typically circular," says the scientist. "But the linear plasmids in yeast may prove to be better shuttles—in part because they reproduce and float freely within the yeast cell's inner space, or cytoplasm."

In contrast, he pointed out, circular plasmids, and even linear plasmids that have been found in filamentous fungi, corn, and other higher plants, are surrounded by membranes of cell structures such as mitochondria or the nuclei.

"These membranes are obstacles to getting DNA in or out of a cell," says Bolen.

Bolen and his colleagues have identified linear plasmids in three strains of *Saccharomycopsis crataegensis*—the grape-dweller—and in one strain of *Pichia inositovora.*

BOB BJORK

Geneticist Paul Bolen analyzes yeast DNA in studies that led to his discovery of linear plasmids in the genetic code of four yeasts. These plasmids show potential as vehicles to transport genes from one microorganism to another. (0987X966-22A)

Linear plasmids [from yeasts] may even work better than the plasmids that genetic engineers now typically use to shuttle genes between microorganisms.

Paul L. Bolen, Agricultural Research Service, Peoria, Illinois

In 1981, Bolen says, Japanese scientists found the first linear plasmids in yeast. The yeast, *Kluyveromyces lactis,* ferments milk sugar (lactose) into lactic acid, which is used in many foods and in pharmaceuticals.

And in 1986, British scientists used parts of that same yeast's linear plasmids to make circular ones. Then they got the circular plasmids to reproduce in both that yeast and *Saccharomyces cerevisiae,* the major yeast used in making beer and bread.

Those experiments demonstrated that pieces of linear plasmids can make circular plasmids replicate and in this instance, can be used to shuttle genes between two yeasts. Bolen is conducting similar studies to see if the newly discovered plasmids have that kind of replication ability. If so, the range of commercially usable yeasts and other microorganisms could be broadened, he says.

Bolen and his colleagues discovered the linear plasmids by screening hundreds of yeast strains from more than 14,000 maintained at the Peoria research center.

"From what we've observed so far, linear plasmids may even turn out to be more prevalent than circular plasmids," he says. "All the newly discovered plasmids were linear. We found circular ones only in species where we already knew they existed."—By **Ben Hardin,** ARS.

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Traffic Lanes Protect Plants

Life is easy for an alfalfa root growing in soil that's light and fluffy, with plenty of tiny pores to hold water and air. But the swathers, rakes, balers, and bale wagons that routinely pass through alfalfa fields compact this soil, squashing pores, slowing infiltration rates, and reducing each plant's growth.

That's why alfalfa hay growers should think about confining the traffic of these heavy machines exclusively to specially designated, semipermanent lanes, say ARS researchers Burl D. Meek and Eric A. Rechel at the U.S. Cotton Research Station in Shafter, California.

In return, growers can expect yields up to 10 percent greater than if wheel traffic continued in the normal uncontrolled manner. On a typical field, such unrestricted traffic usually compacts up to 70 percent of the surface, according to the researchers. That's compared to only 25 percent compacted with controlled traffic.

This information comes from 4 years of measuring the effects of different traffic patterns on alfalfa hay fields in California's San Joaquin Valley, one of the state's prime growing regions for alfalfa hay. The crop, high in protein, is sold primarily as feed for dairy herds.

Typically, alfalfa plants grow so vigorously there that new growth can be cut from the same plant as many as eight times a year, for 3 or 4 years in a row.

"That means you have harvesting equipment going through the field every 30 to 45 days during the growing season," Meek says.

One of the best ways to measure this unwanted compaction is to check the soil's bulk density. Soil compacted until it's rock hard—like that on a dirt road—would have a bulk density of about 2.1 grams per cubic centimeter. In a typical grower's field, soil bulk density was as high as 1.9, the scientists report. In fields where Meek and Rechel restricted traffic to designated paths between the growing beds, density was about 1.6 in the growing beds.

Compaction causes water to infiltrate more slowly. With alfalfa, that's a disadvantage because the longer a plant is surrounded by standing water, the more susceptible it is to disease. The scientists found that irrigation water moved through the traffic-free soil 25 percent faster than through soil in fields with normal traffic.

To keep wheels out of the no-traffic areas, the researchers used a specially designed experimental vehicle, five times wider than the average tractor. This monster machine rolls along raised, semipermanent dirt paths, eliminating all wheel traffic from the beds where alfalfa is growing. Meek says plants in those beds "haven't been touched by a wheel in 4 years." The supertractor carries—suspended above the alfalfa—all the tools needed for planting, tending, and harvesting the crop.

Although the one-of-a-kind, $400,000 machine is ideal for research, alfalfa growers don't need to invest in that kind of equipment, according to Meek. They can reap similar benefits with the machines they already have, just by modifying machines so that all wheels travel along the same path, to minimize the amount of soil surface that's compacted.

It's an investment that should pay off, according to W. Robert Sheesley, director of Cooperative Extension for Fresno County, California, and long-time proponent of controlled traffic. He says alfalfa growers in his state could see yield increases worth $63-$100 million annually if they irrigate properly and keep all of their harvesting equipment on the same track.—By **Marcia Wood**, ARS.

CHRISTOPHER SPRINGMAN

CHRISTOPHER SPRINGMAN

Top: Wide-traction research vehicle pivots at the end of a field in a demonstration of maneuverability. (0583X538-29)

Above: TV monitor in the specially designed experimental vehicle's cab provides a direct view straight ahead and centered over a traffic path. The cab, including seat, steering wheel, and other controls, turns so the driver can either be facing in the direction of field travel or alternately in the direction of road travel. (0583X536-11A)

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USDA Clearinghouse for Plant Germplasm Exchange

On the tiny South Atlantic island of Tristan da Cunha, residents have dug their best potato harvest in more than 30 years. Rejuvenating the staple food crop on the island—population about 300—was "small potatoes" for the world's biggest clearinghouse for the international exchange of plant seeds and cuttings.

The clearinghouse is the U.S. Department of Agriculture's Plant Introduction Office (PIO). Run by the Agricultural Research Service at the Beltsville (Maryland) Agricultural Research Center, the office is part of ARS' National Plant Germplasm System which maintains the country's official plant collections.

"In 1987 alone, we sent more than 55,500 varieties to 104 countries."

George A. White, Agricultural Research Service, Beltsville, Maryland

Germplasm is the basic hereditary genetic material found in seeds and cells of organisms.

"Our primary mission is making germplasm available to researchers around the world who are investigating plant characteristics and developing new varieties," says PIO director George A. White, "but we also help meet immediate needs of countries, even small ones like Tristan da Cunha.

"In 1987 alone, we sent more than 55,500 varieties to 104 countries, he added. "And many other exchanges, perhaps thousands each year, are handled directly between scientists."

In 1986, White's office sent a box of seed potatoes and cuttings to the 64-square-mile island, located halfway between the Falklands and Capetown, South Africa. J. Lindsay Repetto, an island official, had asked for new varieties after reading about ARS' germplasm office in a magazine.

Island residents had grown only one potato variety since the 1950's, according to Repetto, and in the ensuing years, harvests slid downwards as the variety's descendants lost vigor and disease resistance.

"From these new varieties, I was able to grow 150 baskets of potatoes—enough to last a family a full year," Repetto reported to the PIO in February.

While most requests are for a few specific plants, occasionally the PIO handles big jobs.

Last year, Ethiopia asked for help to establish and stock its new National Seed Bank.

The PIO responded with over 1,700 strains of barley and 358 strains of teff, a cereal grain grown extensively in Ethiopia. These were all strains native to Ethiopia that, over the years, had been brought to ARS' National Small Grain Collection.

"If this Ethiopian germplasm had not been collected and held by USDA, it might have been lost forever. Many of these strains probably aren't available in the wild in Ethiopia anymore because of drought and loss of habitat," White says.

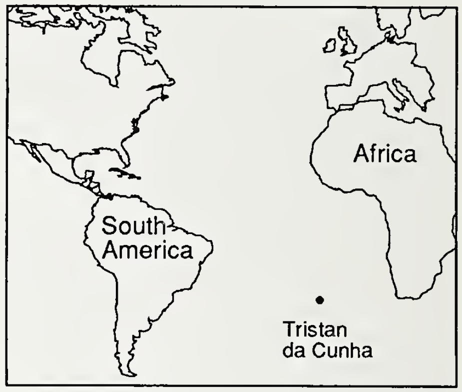
With the more typical requests from scientists, they usually send out about one-sixth of an ounce of seed per accession because of the limited amount of each plant stored in the collections. "For some plants, five grams is 100 or more seeds; for others, 40 seeds," White says. "But that's enough for researchers to start with."

PIO's international exchange of germplasm has had far-reaching effects, according to White. "Take wheat for example. Semidwarf varieties developed from wheat germplasm collected from Japan have influenced the crop around the world."

Strains from this germplasm provided the base material in 1954 for ARS' Orville A. Vogel to develop the high-yielding, disease-resistant spring wheats that sparked the Green Revolution.

Since the PIO is a clearinghouse rather than actually housing any germplasm, it turns to the 42 collections maintained by ARS as well as to universities, private collections, and even the local garden shop to supply seeds and cuttings.

When a scientist from Madagascar called recently to ask for a few varieties of beans that would do well in his wet, tropical climate, White responded by tracking down sources among ARS researchers for 21 of the 22 strains being sought.



Horticulturist Peggy Paciotti filled a Turkish scientist's request for a few seeds of a periwinkle for use as an indicator plant in a potato disease project by buying him a packet of seeds from J.L. Hudson, Seedman. "It's not something we do often, but sometimes it's easier and quicker," Paciotti says.

The PIO also acts as a go-between when plants cannot be transported directly between two foreign countries. Costa Rica, for example, will not import coffee plants or seeds directly from Brazil, to prevent invasion of coffee rust disease.

"But since we don't grow coffee here, we can import seeds from Brazil, grow them in one of our quarantine station greenhouses to check for the disease, and then airfreight the clean coffee plants to Costa Rica," White says. "Costa Rica also passes on clean coffee plants to other Central American countries trying to start or improve coffee industries.

The coffee exchange is part of a PIO program cooperating with the Agency for International Development, which sends out developed crop varieties that are ready for widespread use. In 1987, this program sent out more than 500 accessions to 34 countries, according to White.

"For example, we've sent a lot of forage varieties through AID to Haiti to provide animal feed and to help control soil erosion," White says. "And another transaction included sending date palm varieties to Jordan."

The type of germplasm most frequently requested has shifted during the past 2 years, according to White. "For a long time, cereal grains were the most requested," he says. "But now, since most researchers have received the cereal

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New Permanent Press Cotton Fabric Treatment

Cotton fabrics that have the wrinkle resistance of permanent press can be made with new chemical technology developed by the U.S. Department of Agriculture.

"We think our process opens up a new field that will allow textile makers to produce all-cotton shirts and other apparel that will have the cool feel of cotton, need little if any ironing and still meet industry strength standards," says Clark M. Welch, a chemist with the Agricultural Research Service. "The process works best with textiles containing 50 to 100 percent cotton."

Welch and chemist Bethlehem K. Andrews, based at ARS' Southern Regional Research Center in New Orleans, Louisiana, filed for a patent June 16 on a group of chemicals that produce permanent press—100 percent cotton fabrics that dry smooth without wrinkles even after 65 washings.

Welch says the fabrics are about 20 percent stronger than permanent press fabrics on today's market.

"Polyester or other fabrics are usually blended with cotton to add strength," Welch says. "But polyester doesn't absorb perspiration the way cotton does, so blended shirts don't keep you as cool."

The new fabric treatment has another advantage for consumers: They can take out or put in creases by ironing the fabric. This is difficult to do with permanent press material now on the market.

It will be at least several years, however, before consumers will find these items on clothing store racks. "That's because the chemicals needed to make them won't be available in large quantities at affordable prices for at least 2 years," says Frank X. Werber, ARS' textile expert based at Beltsville, Maryland. "The chemicals are only available for research tests now.

Several textile mills have made and evaluated the new fabrics and "have confirmed our laboratory findings," Welch says. Also, Cotton Incorporated, a trade association sponsored by cotton growers, has tested the fabric treatment and says it has potential.

The new fabric treatment has another important advantage for the textile industry: formaldehyde isn't used. Federal regulatory agencies are pressuring the industry to minimize or remove formaldehyde from current permanent press fabrics because it can irritate the skin and eyes and has caused cancer in laboratory animals. The new process uses chemicals called polycarboxylic acids, which are nontoxic in laboratory studies.

The patent is on four groups of catalysts, or curing agents, that are used to quickly bind the polycarboxylic acids to fibers. The curing agents are similar to chemicals used in baking to control bread rising and in water treatment plants to prevent calcium, magnesium, and other chemicals from building up in pipes and boilers.

In the new process, fabrics soaked in the polycarboxylic acids and the catalysts are heated for about 15 to 90 seconds at temperatures ranging from about 300°F to 500°F. At those high temperatures, the acids unite with the fibers, forming cross-links between the cellulose molecules of cotton fibers and giving wrinkle resistance to the fabric, Welch says.

"The catalysts are the key to our patent," he explains. "Polycarboxylic acids have been known for about 20 years but couldn't be used with previous catalysts. The new ones we're patenting speed up the reaction of the polycarboxylic acids with the fibers. Without them, the process could take an hour. At such high temperatures, the fabric would burn up."

Welch also says that in lab studies the new process gives off no vapors or odors and does not cause yellowing of the fabric. Previous attempts to use polycarboxylic acids caused off-colors and other problems.

Also, the new fabrics could save the industry money because they can be colored by certain kinds of dyes after being permanent-press treated. Welch says this is important because manufacturers can make clothing out of permanent press fabrics and dye the garments after they find out which colors are most popular with consumers. Textile makers must now dye first and then put in permanent-press treatment, which means they sometimes have large stocks of certain colors that won't sell.

For technical information, contact Clark M. Welch, USDA-ARS Southern Regional Research Center, P.O. Box 19687, New Orleans, LA 70179 (504) 286-4272. Patent application serial number not yet assigned.—By **Sean Adams,** ARS.

Obtaining Licenses for USDA Patents

For information on licensing patents listed on this page or to receive a catalog of USDA patents, contact Ann Whitehead, coordinator, National Patent Program, USDA-ARS, Room 401, Bldg. 005, Beltsville, MD 20705.

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germplasm they wanted, more requests are coming for forage plants and for oilseed crops like soybeans. There has also been an upswing in requests for food and feed legumes, chickpeas, and beans."

Once in a while, Paciotti says a request cannot be filled. "A researcher from India, who regularly corresponds with us, asked if our collections could provide several plant varieties and a suitable bachelor for his 18-year-old daughter," she says. "We had the plants; we haven't found the bachelor yet."—By **Kim Kaplan,** ARS.

For details, contact George A. White, Plant Introduction Officer, USDA-ARS Germplasm Services Laboratory, Beltsville Agricultural Research Center, Beltsville, MD 20705 (301) 344-3328. ♦

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